DOI:
10.1109/COMCAS.2017.8244828

Antenna design by using specialist tool for the 3D EM simulation of high frequency components

Irina L. Alborova[1*], Maria Koutsoupidou[2,3], Andrey Rogozin[1],
Panagiotis Kosmas[3,4], Lesya N. Anishchenko[1]

[1]Bauman Moscow State Technical University, Moscow, 105005, Russia; [2]National Technical University of Athens, 15780, Greece; [3]King's College London, WC2R 2LS, UK; [4]MediWiSe | Medical Wireless Sensing Ltd , London, E1 2AX, UK

***Abstract* — This paper presents the study results of the Self-complementary Bow-tie Antenna (SCBT-antenna) for microwave imaging. The most important milestones are to select the optimal antenna characteristics for MWI and to model and simulate the array element using specialized software packages. The antenna was modelled on an aluminum nitride substrate with a dielectric constant of 8.6 and thickness of 1.5 mm. The breast phantom was presented as a parallelepiped with dimensions of 100x100x52 mm, which consist two layers (adipose tissue and 2 mm thickness skin) and a spherical inclusion imitating the tumor. The simulation results obtained from CST software showed a −10 dB return loss bandwidth from 1.75 to 2.36 GHz in free space and 1.45-1.77 GHz when the antenna was placed at the proximity of the tissue. Penetration depth was approximately 30-40 mm. Further investigation of the antenna is required using phantoms with more anatomical details.**

***Index Terms* — Antenna design, CST simulation, Bow-tie Antenna, tumor detection, dielectric inhomogeneity detection.**

I. Introduction

The development and improvement of imaging modalities for the early detection of breast cancer remains an active area of research. Microwave imaging has attracted significant research interest as a novel modality for breast cancer detection that presents important advantages over other techniques currently applied in clinical practice [1], [2].

It is known that the dielectric properties of normal and malignant breast tissues differ even at the earliest stage of tumor genesis [3]. Thus, microwave imaging, which detects dielectric in the medium, could be used for early stage breast tumor detection.

This paper presents the study results of the Self-complementary Bow-tie Antenna (SCBT-antenna) for microwave imaging. The most important milestones are to select the optimal antenna characteristics for MWI and to model and simulate the array element using specialized software packages.

II. Antenna design

The antenna design is a modification of the simple triangular monopole antenna [4]: the ground plane was extended and a mirror triangular slot was added, while the microstrip feed line was bended by 90 degrees. The antenna was modelled on an aluminum nitride substrate (60 mm x 85 mm) with a dielectric constant of 8.6 and thickness of 1.5 mm. The high epsilon substrate was used in order to achieve good matching with the tissue. Geometry of the antenna and screenshot of the model are shown in Fig. 1, 2.

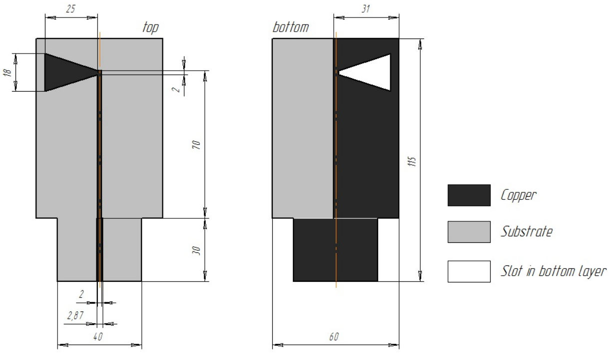


Fig. 1. Geometry of the self-complementary bow-tie antenna (SCBT-antenna).

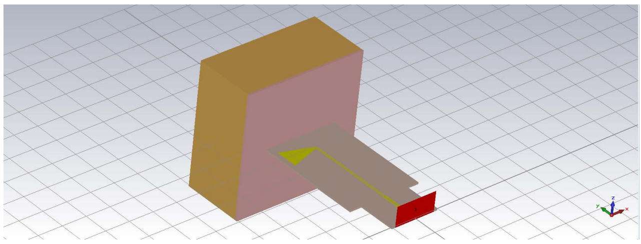


Fig. 2. Screenshot of the model in CST Studio Suite.

The breast phantom was modelled as a parallelepiped comprising a layer of skin (2mm thick) and a layer of adipose tissue (50 mm thick). The tissues' dielectric properties were found in literature [5]. Additionally, a tumor mimicking small spherical inclusion of 5 mm radius was placed in the adipose tissue at a 2 mm distance from the skin. The dielectric contrast of the tumor to the fat tissue was 10:1. The antenna was placed with its small side (60 mm) lying on the tissue surface of 100 mm x100 mm.

III. Results

The setup was modelled with CST Microwave Studio® in the 0.1 – 4 GHz range and the S_{11} and E-field results are displayed in Fig. 3 and 4 respectively.

The simulation results obtained from the CST software showed a −10 dB return loss bandwidth of 1.75 to 2.36 GHz in free space and 1.45-1.77 GHz with tissue (Fig. 3). The presence of the tumor resulted to a clear drop of 5 dB at the antenna's reflection coefficient (Fig. 3c). The E-field distribution inside the tissue is displayed in Fig. 4. The color map was clamped to a maximum of 200 V/m. Penetration depth was approximately 30-40 mm. The lower cut-off frequency was 1.45 GHz and good penetration into the tissue was achieved without immersing the antenna into a matching medium. Further investigation of the antenna is required using phantoms with more anatomical details.

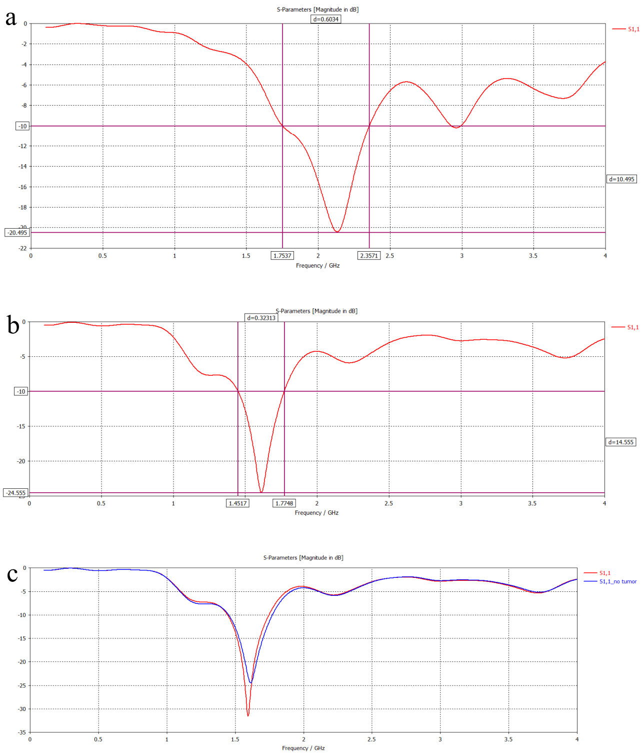
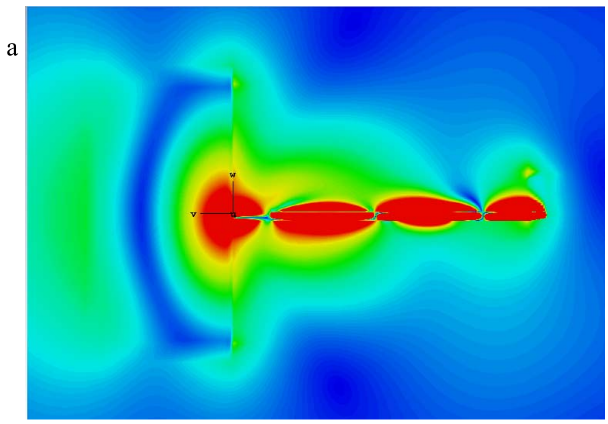


Fig. 3. Simulated return loss: (a) without phantom; (b) phantom without inclusion; (c) phantom with 10 mm inclusion.



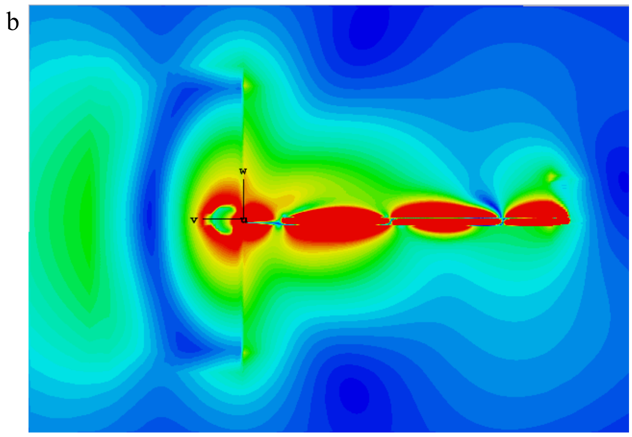


Fig. 4. E-field distributions of the SCBT-antenna: (a) without inclusion; (b) with 10 mm inclusion.

IV. Conclusion

The simulation results obtained from CST software showed a −10 dB return loss bandwidth from 1.75 to 2.36 GHz in free space and 1.45-1.77 GHz when the antenna was placed at the proximity of the tissue. Penetration depth was approximately 30-40 mm. Further investigation of the antenna is required using phantoms with more anatomical details.

Acknowledgement

The results, published in the article, have been obtained in the framework of the implementation of the project part of the Russian Foundation for Basic Research (grant No. 26 16-37-00276) and in the framework of Short-Term Scientific Mission programme in MediWiSe (COST Action TD 1301 – MiMed).

References

[1] M. Koutsoupidou, I.S. Karanasiou, C.G. Kakoyiannis, E. Groumpas, C. Conessa, N. Joa-chimowicz, and B. Duchene, "Evaluation of a tumor detection microwave system with a realistic breast phantom", *Microwave and Optical Technology Letters*, vol. 59, no. 1, pp. 6-10, 2017.

[2] L.N. Anishchenko, A.A. Demendeev, S.I. Ivashov, V.V. Razevig, I.A. Vasiliev, and T.D. Bechtel, Holographic radar in breast cancer imaging, *2012 IEEE National Radar Conference - Proceedings*, art. no. 6212284, pp. 1004-1007, 2012.

[3] M. Lazebnik, L. McCartney, D. Popovic, C.B. Watkins, M.J. Lindstrom, J. Harter, S. Se-wall, A. Magliocco, J.H. Booske, M. Okoniewski, and S.C. Hagness, "A large – scale study of the ultrawideband microwave dielectric properties of normal breast tissue obtained from reduction surgeries", *Physics in Medicine and Biology*, vol. 52, pp. 2637-2656, 2007.

[4] K.H. Sayidmarie, and Y.A. Fadhel, "A planar self-complementary bow-tie antenna for UWB applications", *Progress In Electromagnetics Research C*, vol. 35, pp. 253–267, 2013.

[5] D. Andreuccetti, R. Fossi, and C. Petrucci, "An Internet resource for the calculation of the dielectric properties of body tissues in the frequency range 10 Hz - 100 GHz", IFAC-CNR, Florence (Italy), 1997. Based on data published by C.Gabriel et al. in 1996. URL: http://niremf.ifac.cnr.it/tissprop/.